KEITHLEY

Model 2000-SCAN
Scanner Card
Instruction Manual

Contains Operating and Servicing Information

KEITHLEY

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Manual Print History

The print history shown below lists the printing dates of all Revisions and Addenda created for this manual. The Revision Level letter increases alphabetically as the manual undergoes subsequent updates. Addenda, which are released between Revisions, contain important change information that the user should incorporate immediately into the manual. Addenda are numbered sequentially. When a new Revision is created, all Addenda associated with the previous Revision of the manual are incorporated into the new Revision of the manual. Each new Revision includes a revised copy of this print history page.

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Safety Precautions

The following safety precautions should be observed before using this product and any associated instrumentation. Although some instruments and accessories would normally be used with non-hazardous voltages, there are situations where hazardous conditions may be present.

This product is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read the operating information carefully before using the product.

The types of product users are:

Responsible body is the individual or group responsible for the use and maintenance of equipment, for ensuring that the equipment is operated within its specifications and operating limits, and for ensuring that operators are adequately trained.

Operators use the product for its intended function. They must be trained in electrical safety procedures and proper use of the instrument. They must be protected from electric shock and contact with hazardous live circuits.

Maintenance personnel perform routine procedures on the product to keep it operating, for example, setting the line voltage or replacing consumable materials. Maintenance procedures are described in the manual. The procedures explicitly state if the operator may perform them. Otherwise, they should be performed only by service personnel.

Service personnel are trained to work on live circuits, and perform safe installations and repairs of products. Only properly trained service personnel may perform installation and service procedures.

Exercise extreme caution when a shock hazard is present. Lethal voltage may be present on cable connector jacks or test fixtures. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V RMS, 42.4V peak, or 60VDC are present. **A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.**

Users of this product must be protected from electric shock at all times. The responsible body must ensure that users are prevented access and/or insulated from every connection point. In some cases, connections must be exposed to potential human contact. Product users in these circumstances must be trained to protect themselves from the risk of electric shock. If the circuit is capable of operating at or above 1000 volts, **no conductive part of the circuit may be exposed.**

As described in the International Electrotechnical Commission (IEC) Standard IEC 664, digital multimeter measuring circuits (e.g., Keithley Models 175A, 199, 2000, 2001, 2002, and 2010) are Installation Category II. All other instruments' signal terminals are Installation Category I and must not be connected to mains.

Do not connect switching cards directly to unlimited power circuits. They are intended to be used with impedance limited sources. NEVER connect switching cards directly to AC mains. When connecting sources to switching cards, install protective devices to limit fault current and voltage to the card.

Before operating an instrument, make sure the line cord is connected to a properly grounded power receptacle. Inspect the connecting cables, test leads, and jumpers for possible wear, cracks, or breaks before each use.

For maximum safety, do not touch the product, test cables, or any other instruments while power is applied to the circuit under test. ALWAYS remove power from the entire test system and discharge any capacitors before: connecting or disconnecting cables or jumpers, installing or removing switching cards, or making internal changes, such as installing or removing jumpers.

Do not touch any object that could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface capable of withstanding the voltage being measured.

The instrument and accessories must be used in accordance with its specifications and operating instructions or the safety of the equipment may be impaired.

Do not exceed the maximum signal levels of the instruments and accessories, as defined in the specifications and operating information, and as shown on the instrument or test fixture panels, or switching card.

When fuses are used in a product, replace with same type and rating for continued protection against fire hazard.

Chassis connections must only be used as shield connections for measuring circuits, NOT as safety earth ground connections.

If you are using a test fixture, keep the lid closed while power is applied to the device under test. Safe operation requires the use of a lid interlock.

If a screw is present, connect it to safety earth ground using the wire recommended in the user documentation.

The symbol on an instrument indicates that the user should refer to the operating instructions located in the manual.

The symbol on an instrument shows that it can source or measure 1000 volts or more, including the combined effect of normal and common mode voltages. Use standard safety precautions to avoid personal contact with these voltages.

The **WARNING** heading in a manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading in a manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

Instrumentation and accessories shall not be connected to humans.

Before performing any maintenance, disconnect the line cord and all test cables.

To maintain protection from electric shock and fire, replacement components in mains circuits, including the power transformer, test leads, and input jacks, must be purchased from Keithley Instruments. Standard fuses, with applicable national safety approvals, may be used if the rating and type are the same. Other components that are not safety related may be purchased from other suppliers as long as they are equivalent to the original component. (Note that selected parts should be purchased only through Keithley Instruments to maintain accuracy and functionality of the product.) If you are unsure about the applicability of a replacement component, call a Keithley Instruments office for information.

To clean an instrument, use a damp cloth or mild, water based cleaner. Clean the exterior of the instrument only. Do not apply cleaner directly to the instrument or allow liquids to enter or spill on the instrument. Products that consist of a circuit board with no case or chassis (e.g., data acquisition board for installation into a computer) should never require cleaning if handled according to instructions. If the board becomes contaminated and operation is affected, the board should be returned to the factory for proper cleaning/servicing.

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1
General Information

Introduction

This section contains general information about the Model 2000-SCAN scanner card. The Model 2000-SCAN provides 10 channels of 2-pole relay switching. The channels can be configured for 4-pole operation.

Section 1 is arranged in the following manner:

Features

Warranty information

Manual addenda

Safety symbols and terms

Specifications

Unpacking and inspection

Repacking for shipment

Features

The Model 2000-SCAN is a scanner card designed to be installed in the Model 2000 Multimeter, Model 2001 Multimeter, and Model 2002 Multimeter.

Key features include:

- Ten channels of 2-pole relay input.
- Channels configurable for 4-pole operation.
- Multiplex one of ten 2-pole, or one of five 4-pole channels into a Model 2000/2001/2002 Multimeter.

Warranty information

Warranty information is located at thew front of this instruction manual. Should your Model 2000-SCAN require warranty service, contact the Keithley representative or authorized repair facility in your area for further information. When returning the scanner card for repair, be sure to fill out and include the service form at the back of this manual in order to provide the repair facility with the necessary information.

Manual addenda

Any improvements or changes concerning the scanner card or manual will be explained in an addendum included with the card. Addenda are provided in a page replacement format. Simply replace the obsolete pages with the new pages.

Safety symbols and terms

The following symbols and terms may be found on an instrument or used in this manual.

The symbol on an instrument indicates that the user should refer to the operating instructions located in the instruction manual.

The symbol on an instrument shows that high voltage may be present on the terminal(s). Use standard safety precautions to avoid personal contact with these voltages.

The **WARNING** heading used in this manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading used in this manual explains hazards that could damage the scanner card. Such damage may invalidate the warranty.

Specifications

Model 2000-SCAN specifications are found in Appendix A. These specifications are exclusive of the multimeter specifications.

Unpacking and inspection

Inspection for damage

The Model 2000-SCAN is packaged in a re-sealable, anti-static bag to protect it from damage due to static discharge and from contamination that could degrade its performance. Before removing the card from the bag, observe the precautions below on handling.

Handling precautions

- Always grasp the card by the side edges and covers. Do not touch the board surfaces or components.
- When the card is not installed in a multimeter, keep the card in the anti-static bag, and store it in the original packing carton. After removing the card from its anti-static bag, inspect it for any obvious signs of physical damage. Report any such damage to the shipping agent immediately.

Shipment contents

The following items are included with every Model 2000-SCAN order:

- Model 2000-SCAN Scanner Card
- Model 2000-SCAN Instruction Manual
- CA-109 test lead set for output connections (two red, two black)
- Additional accessories as ordered

Instruction manual

If an additional Model 2000-SCAN Instruction Manual is required, order the manual package, Keithley part number 2000-SCAN-901-00. The manual package includes an instruction manual and any pertinent addenda.

Repacking for shipment

Should it become necessary to return the Model 2000-SCAN for repair, carefully pack the unit in its original packing carton or the equivalent, and include the following information:

- Advise as to the warranty status of the scanner card.
- Write ATTENTION REPAIR DEPARTMENT on the shipping label.
- Fill out and include the service form located at the back of this manual.

2
Card Connections and Installation

Introduction

WARNING ***The procedures in this section are intended only for qualified service personnel. Do not perform these procedures unless you are qualified to do so. Failure to recognize and observe normal safety precautions could result in personal injury or death.***

This section includes information on making connections to the Model 2000-SCAN and on installing the card in a Model 2000/2001/2002 Multimeter. This section is ar-ranged as follows:

Handling precautions — Explains precautions that must be followed to prevent contamination to the scanner card assembly. Contamination could degrade the performance of the scanner card.

Connections — Covers the basics for connecting external circuitry to the scanner card.

Typical connection schemes — Provides some typical connection schemes for 2-pole and 4-pole operation.

Card installation and removal — Summarizes the procedure to install the scanner card in a multimeter, outlines scanner card output connections, and describes how to remove the card.

Handling precautions

To maintain high impedance isolation between channels, care should be taken when handling the scanner card to avoid contamination from such foreign materials as body oils. Such contamination can substantially lower leakage resistances, degrading card performance. To avoid possible contamination, always grasp the scanner card by the side edges or covers. Do not touch board surfaces, components, or areas adjacent to electrical contacts.

Dirt build-up over a period of time is another possible source of contamination. To avoid this problem, operate the multimeter and scanner card in a clean environment. If the card becomes contaminated, it should be thoroughly cleaned as explained in Section 4 "Handling and cleaning precautions".

Connections

This paragraph provides the information necessary to connect your external test circuitry to the scanner card.

WARNING ***The following connection information is intended to be used by qualified service personnel. Failure to recognize and observe standard safety precautions could result in personal injury or death.***

NOTE *All connecting wires or leads must be connected to the card before it is installed in a multimeter.*

Card configuration

Figure 2-1 shows a simplified schematic diagram of the Model 2000-SCAN. The scanner card has ten input channels and two outputs. Channels 1-10 are all switched by relays.

4-pole paired channels are as follows:

- Channels 1 and 6
- Channels 2 and 7
- Channels 3 and 8
- Channels 4 and 9
- Channels 5 and 10

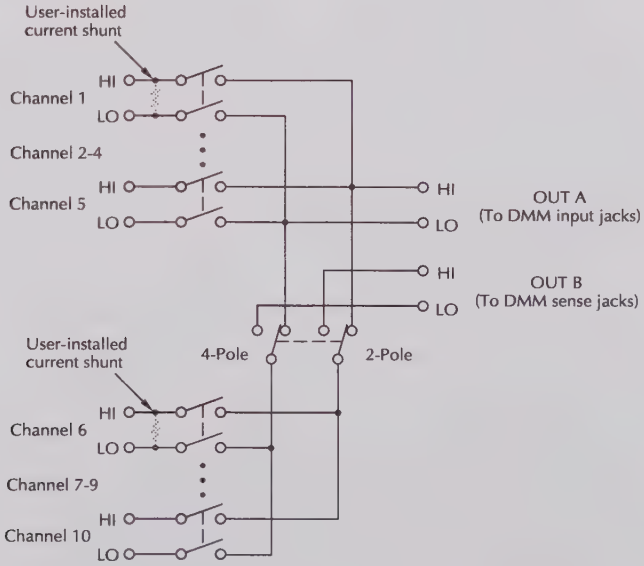


Figure 2-1
Model 2000-SCAN simplified schematic

Card connectors

Figure 2-2 shows the input/output connectors for the card. Card connections include:

- CH 1-10 (channels 1-10): HI and LO input terminals are provided for each of the 10 channels on the card.
- OUT A: HI and LO output connections for all ten channels in the 2-pole mode or channels 1-5 in the 4-pole mode.
- OUT B: HI and LO output connections for channels 6-10 in the 4-pole mode.

In order to gain access to the connections, first open the plastic shield by pressing in on the locking tab. Swing the shield away from the circuit board.

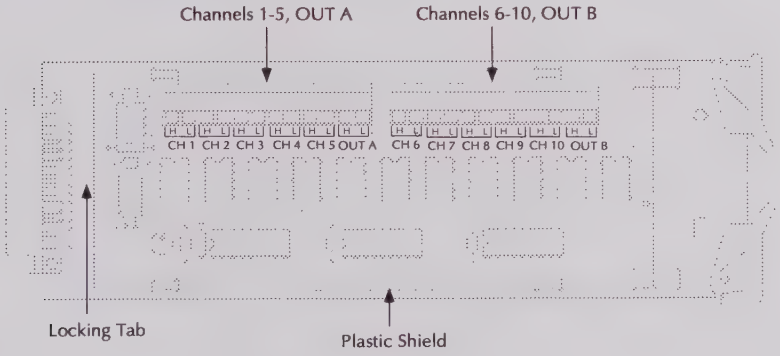


Figure 2-2
Card connectors

Wiring procedure

Perform the following procedure to wire circuitry to the screw terminals on the scanner card.

WARNING ***Make sure all power is off and any stored energy in external circuitry is discharged before connecting or disconnecting wires.***

CAUTION ***Mechanical shock may open or close latching relays on the scanner card. Before enabling any external sources, open all relays by inserting the Model 2000-SCAN into the multimeter and turning on the power.***

1. Open the plastic shield to gain access to the connectors.
2. Strip approximately 5/16" of insulation from the end of each wire, then twist the strands together.

NOTE *#22 AWG stranded wire is recommended for scanner card connections.*

3. Loosen the screw terminal, then insert the wire into the access hole.
4. While holding the wire in place, tighten the connector screw securely.
5. Repeat steps 1 through 3 for each wire to be connected.
6. Dress input wires through the cable clamp, as discussed in Section 2 "Dressing leads".

Output connections

Use the supplied test leads for scanner output connections. Connect red leads to the output (OUT A and OUT B) HI terminals, and connect black leads to the output LO terminals. See Figure 2-3 for details. Dress output test leads through the cable clamp, as described in Section 2 "Dressing leads". After all wires are connected and secure, close the plastic shield, and secure it with the locking tab.

NOTE *If you intend to use the scanner card only in the 2-pole mode, it is not necessary to connect output leads to both OUT A and OUT B. Use only OUT A for the 2-pole mode.*

After the scanner card is installed, the output leads must be connected to the multimeter rear panel input jacks. See Section 2 "Output connections to multimeter" for details.

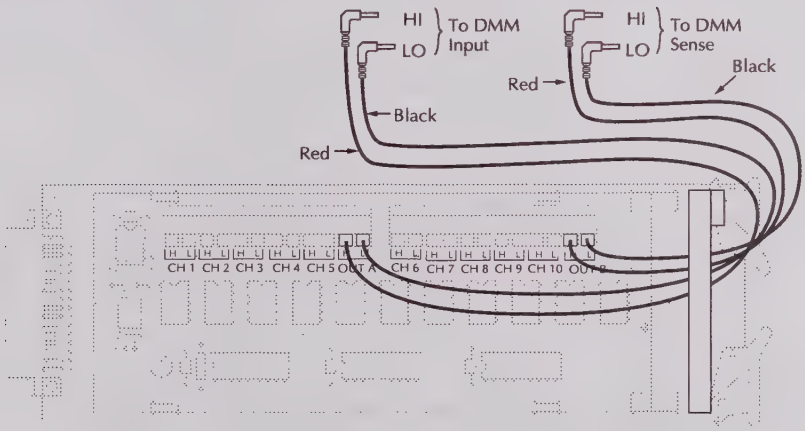


Figure 2-3
Output connections

Note: OUT B connections not required for 2-pole operation. Plastic shield not shown.

Dressing leads

After wires are connected to the terminal blocks, they should be dressed through the cable clamp as shown in Figure 2-4. To do so, unlatch the clip that holds the cable clamp together, then route all wires flat against the lower half of the clamp. Clamp the wires down, then secure the clamp with the metal clip unlatched earlier.

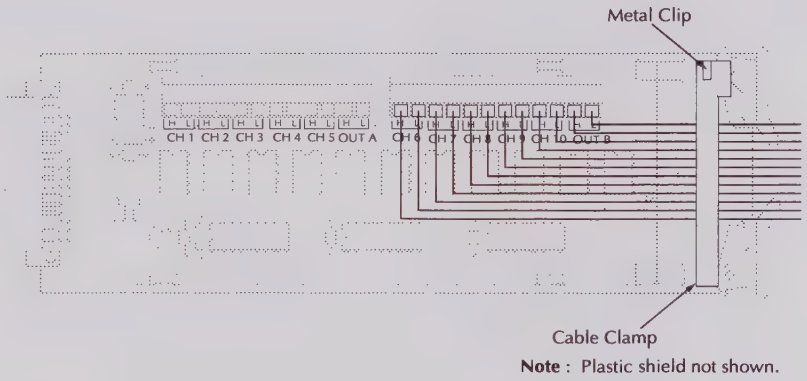


Figure 2-4
Routing wires through cable clamp

Typical connecting schemes

The following paragraphs discuss typical connections for the scanner card.

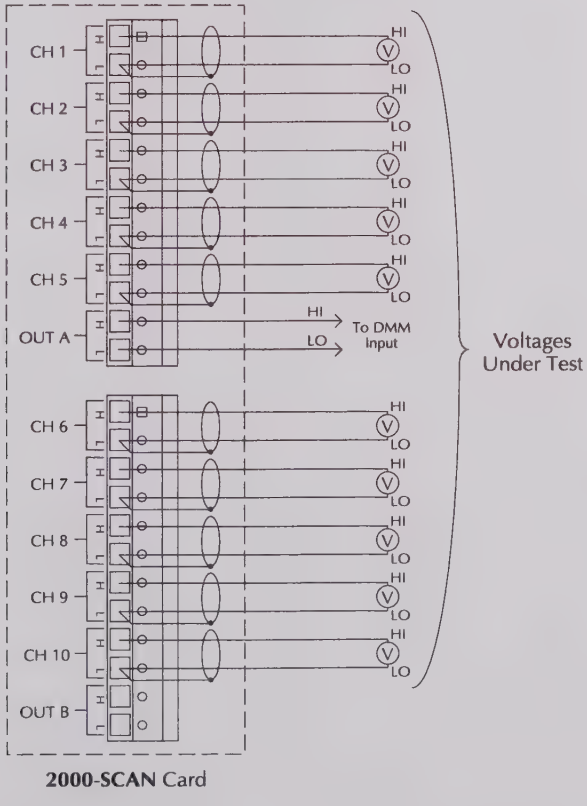
Voltage connections

Figure 2-5 shows typical connections for voltage measurements. Note that all channels are used in the 2-pole mode, and that up to 10 voltage sources can be switched with this configuration. This basic configuration can be used for the following types of measurements:

- DCV
- ACV
- Frequency (voltage only)

All channels (1-10) can be used with this configuration.

Figure 2-5
Connections for voltage scanning



Resistance connections

2-Pole connections

Figure 2-6 shows typical 2-pole resistor test connections. The 2-pole resistance configuration can be used to test up to ten DUTs.

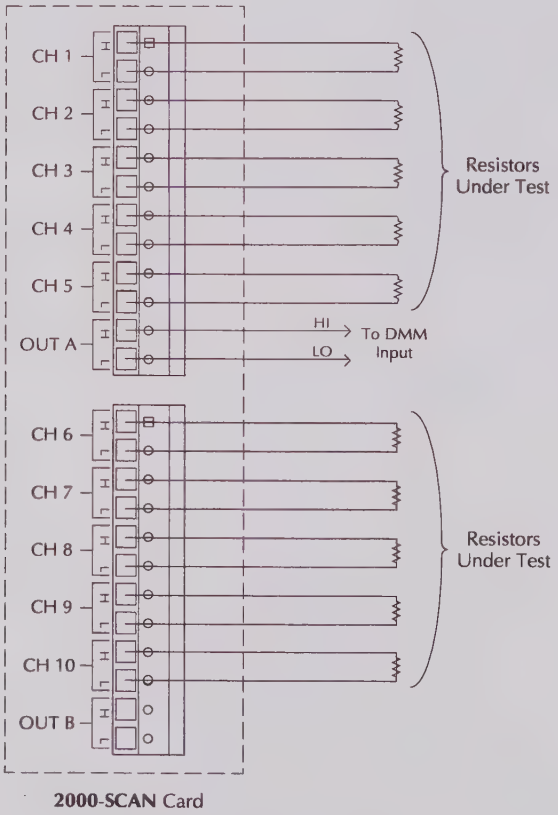


Figure 2-6
Typical connections for 2-wire resistance scanning

4-Pole connections

Typical 4-pole resistance connections are shown in Figure 2-7. This general configuration can be used with all channels to scan:

- 4-wire resistance measurements.
- 4-wire RTD temperature measurements (Model 2001 and 2002 multimeters).

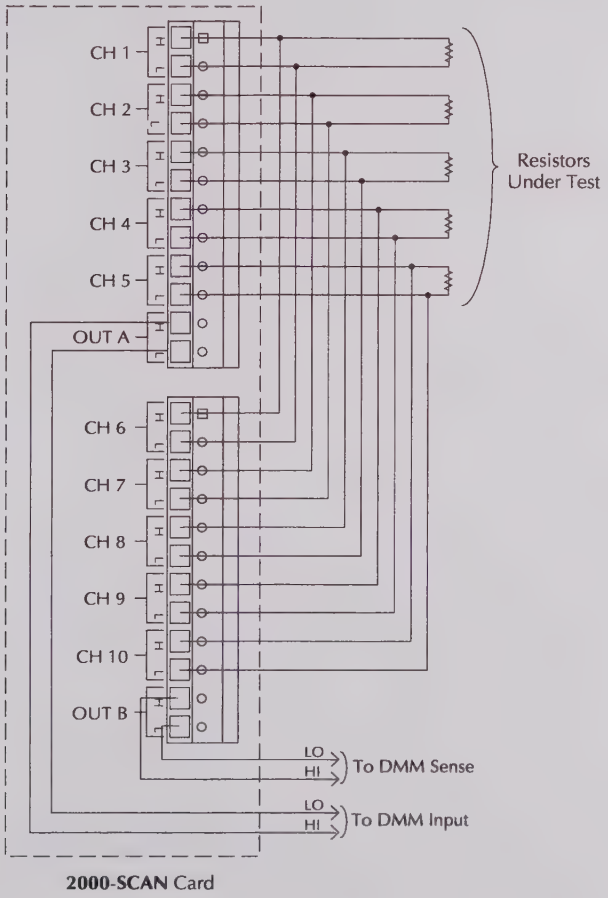


Figure 2-7
Typical connections for 4-wire resistance scanning

Current measurements

Current shunts can be installed on the circuit board to allow indirect AC and DC current measurements to be made through channels 1 and 6 only. The following paragraphs discuss installing current shunts and the basic methods used to determine currents.

CAUTION ***Board mounted current shunt resistors can be installed only for channels 1 and 6. A channel that has been modified with a current shunt resistor should not be used for voltage or resistance measurements.***

Current shunt locations

Figure 2-8 shows the locations for the user-installable current shunts. Location R145 is for channel 1 and R146 is for channel 6.

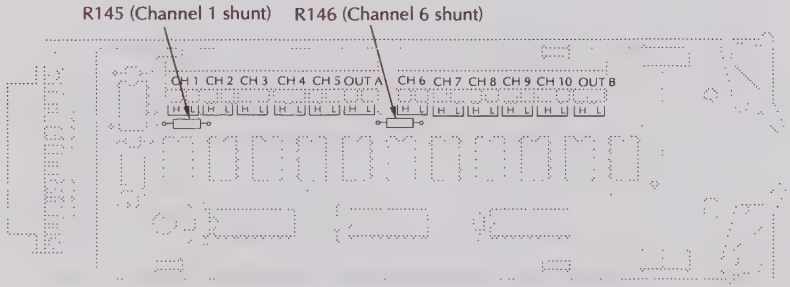


Figure 2-8
Current shunt locations

Recommended current shunt values

Hole spacing on the circuit board is intended for 1/4W resistors. The resistance value will depend on the current you intend to measure; 1kΩ resistors should be optimum for many applications. A 1kΩ resistor will allow you to switch currents up to 15mA without exceeding the power rating of the resistor.

For larger currents, decrease the shunt value. Conversely, the shunt value can be increased for smaller currents.

CAUTION ***Do not exceed the maximum card signal levels:***

- ***DC signals: 110V DC, 1A switched, 30 VA maximum.***
- ***AC signals: 125V AC rms or 175V AC peak, 1A switched, 62.5 VA maximum.***

Board cleaning

NOTE *Failure to observe the following precautions may result in degraded card performance.*

When soldering resistors, be sure not to touch areas not associated with resistor installation or spread flux around to other areas of the circuit board. Use solder with an OA (organic activated) flux. The circuit board should be thoroughly cleaned with pure water after soldering to remove all contaminants. After cleaning with water, swab the area with pure methanol, then allow the board to dry for several hours in a 50°C environment before use.

Current measurements

Even with the current shunts installed, you cannot make direct current measurements with the scanner card. Instead, you must close the channel to be measured, and measure the voltage across the shunt. The current can then be calculated as follows:

Where: I = current being determined
V= voltage measured by multimeter
R= shunt resistance value

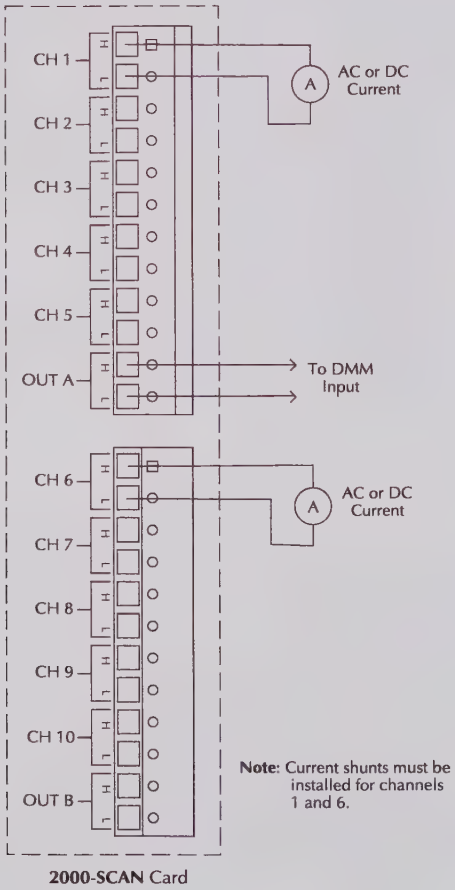
Instead of manually calculating current, set up a Model 2000/2001/2002 mX + b math calculation function. (Here, m = 1/R and b = 0.). The multimeter will then display the actual current value. Refer to the multimeter manuals for details on using math functions.

Current connections

Figure 2-9 shows typical connections for measuring currents using the Model 2000-SCAN with current shunts installed. As noted previously, only channels 1 and 6 have current shunts installed, and this configuration can be used to scan the following:

- DC current
- AC current

Figure 2-9
Current connections



Card installation and removal

This paragraph explains how to install and remove the Model 2000-SCAN card assembly from the Model 2000 Multimeter.

WARNING ***Installation or removal of the Model 2000-SCAN should be performed only by qualified service personnel. Failure to recognize and observe standard safety precautions could result in personal injury or death.***

NOTE *To prevent contamination to the scanner card that could degrade performance, handle the card assembly only by the card edges and covers.*

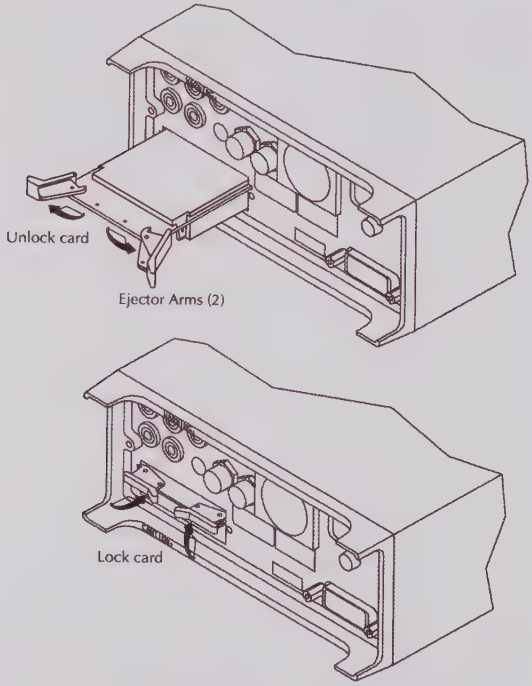
Wiring connections must made before installing the scanner card. See Section 2 "Typical connecting schemes" for wiring details.

Scanner Card Installation

Perform the following steps and refer to Figure 2-10 to install the card assembly in the multimeter:

WARNING ***Turn off power to all instrumentation (including the multimeter) and disconnect all line cords. Make sure all power is removed and any stored energy in external circuitry is discharged.***

Figure 2-10
Card installation



Note: Card installation in a Model 2001/2002 is shown. For installation in Model 2000, turn card over.

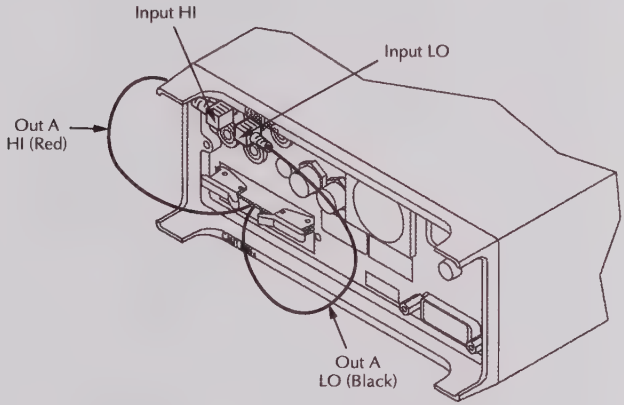
1. Remove the cover plate from the OPTION SLOT on the rear panel of the multimeter. To Do so, pry out the two fasteners, then remove the Cover plate.
2. Slide the card edges into the guide rails inside the multimeter (solder side up for Model 2001/2002, component side up for Model 2000).
3. With the ejector arms in the unlocked position, carefully push the card all the way forward until the arms engage the ejector clips. Push both arms inward to lock the card into the multiMeter.
4. After installation, connect the output leads to the multimeter as discussed below.

Output connections to multimeter

After installation, connect the scanner card output leads to the multimeter rear panel jacks as follows:

- For 2-pole operation, connect OUT A HI (red) to INPUT HI, and connect OUT A LO (black) to INPUT LO. See Figure 2-11.

Figure 2-11
2-pole output connections

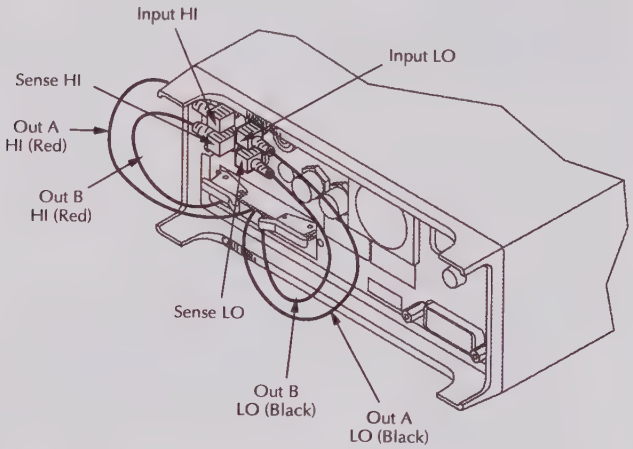


Note: Card installation in a Model 2001/2002 is shown. For installation in Model 2000, turn card over.

NOTE *Be sure to select the rear inputs with the multimeter front panel INPUTS switch when using the scanner.*

- For 4-pole operation, connect OUT A HI (red) to INPUT HI, and connect OUT A LO (black) to INPUT LO. Also connect OUT B HI (red) to SENSE HI, and connect OUT B LO (black) to SENSE LO. See Figure 2-12.

Figure 2-12
4-pole output connections



Note: Card installation in a Model 2001/2002 is shown. For installation in Model 2000, turn card over.

Scanner card removal

Follow the steps below to remove the scanner card from the multimeter:

WARNING ***Turn off power to all instrumentation (including the multimeter) and disconnect all line cords. Make sure all power is removed and any stored energy in external circuitry is discharged.***

1. Unlock the card by pulling the latches outward.
2. Carefully slide the card out of the multimeter.
3. If the multimeter is to be operated without the scanner card installed, install the cover plate over the OPTION SLOT.

3
Operation

Introduction

This section contains detailed information on front panel and IEEE-488 bus operation of the Model 2000-SCAN. The information in this section is organized as follows:

Signal limitations — Summarizes the maximum signals that can be applied to the Model 2000-SCAN.

Scanner card detection — Discusses how the scanner card is detected and how to determine whether or not the card is installed with a bus command.

Model 2000 front panel scanner controls and IEEE-488 bus scanner commands — Gives an overview of the Model 2000 Multimeter front panel controls and corresponding IEEE-488 bus commands used to control the scanner card.

IEEE-488 bus scanner commands — Summarizes bus commands necessary to control the scanner card by either the Model 2000 or Model 2001/2002 Multimeters.

Model 2001/2002 front panel scanner controls and IEEE-488 bus scanner commands — Gives and overview of the Model 2001/2002 Multimeter front panel controls and corresponding IEEE-488 bus commands used to control the scanner card.

RTD temperature measurements — Provides detailed information on using RTD probes when scanning (Model 2001/2002).

Typical applications — Discusses typical applications for the Model 2000-SCAN.

Measurement considerations — Discusses a number of measurement considerations that should be taken into account when using the scanner.

NOTE ***Before using the Model 2000-SCAN scanner card, you should be thoroughly familiar with the operation of the Model 2000 /2001/2002 Multimeter. See the multimeter manual for details.***

Signal limitations

CAUTION ***To prevent damage to the Model 2000-SCAN, do not exceed the maximum signal level specifications of the card.***

Relay input signal limitations

Channels 1-10 are all relay inputs. To prevent over-heating or damage to the relays, never exceed the following maximum signal levels for these channels:

DC signals: 110V DC, 1A switched, 30VA (resistive load).

AC signals: 125V rms or 175V AC peak, 1A switched, 62.5VA (resistive load).

Scanner card detection

Power-up detection

The scanner card is detected only at power-on. If the card is plugged in after the power is turned on, the card will not be recognized as being present by the multimeter.

CAUTION ***Plugging in the scanner card with power turned on may result in damage to both the Model 2000-SCAN and the multimeter.***

If the card is not present at power-on, scanner bus commands or queries will generate a "Missing hardware error", and front panel operations pertaining to the scanner will inform you that no scanner is present.

Scanner option bus query

*OPT? is an IEEE 488.2 common query which will allow you determine whether or not a scanner card is installed. The response to this query indicates whether or not a scanner card is present as follows:

- 0: Scanner not installed.
- 200X-SCAN: Scanner installed. (The Model 2000 does not distinguish among scanner cards.)

Refer to Model 2000/2001/2002 manuals for more details on using the *OPT? query.

Model 2000 Multimeter front panel scanner controls and SCPI scanner commands

The following paragraphs give an overview of the various Model 2000 Multimeter front panel controls and corresponding SCPI commands used with the Model 2000-SCAN.

Closing channels

Front Panel

Use the front panel CLOSE key to close specific channels as follows:

1. From the normal display, press the CLOSE key. The instrument will display the following:

   CLOSE CHAN: 01

2. Use the ◄ , ► , ▲ and ▼ keys to select the channel you wish to close, then press ENTER.

   The number of the closed channel will be displayed on the front panel along with normal readings. Selecting a different channel from the one presently closed will cause the closed channel to open and allow a settling time before closing the selected channel.

3. The ◄ and ► keys alone will also close the channels. Press the ◄ and ► keys until the channel annunciator you wish closed appears on the display.

Remote interface

Use the :ROUTe:CLOSe command to close the desired channel. For example, if you wish to close channel 4, use the following command:

```
PRINT #1, "output 16; :route:close (@4)"
```

Use the :ROUTe:MULTiple:CLOSe command to close multiple channel. For example, if you wish to close channels 1, 3 and 5, use the following command:

```
PRINT #1, "output 16; :route:multiple:close (@1,3,5)"
```

Note that closing channel 11 selects the 4-pole operating mode.

Opening channels

Front Panel

Use the front panel OPEN key to open all of the card channels.

Remote interface

Use the :ROUTe:OPEN:ALL command to open all of the channels. The command is as follows:

```
PRINT #1, "output 16; :route:open:all"
```

Use the :ROUTe:MULTiple:OPEN command to open specified channels. For example, if you wish to open channels 1, 3 and 5, use the following command:

```
PRINT #1, "output 16; :route:multiple:open (@1,3,5)"
```

Note that opening channel 11 selects the 2-pole operating mode.

Selecting measurement function

This section describes how to select a specific measurement function for an internal channel.

1. Use the ◄ and ► keys to select the desired channel.
2. Select the desired measurement function with the keys on the front panel. The various measurement functions available are:

DCV: DC volts
ACV: AC volts
Ω2W: 2-wire ohms
Ω4W: 4-wire ohms (channels 1-5)
FREQ: frequency
PERIOD: period
TEMP: simulated temperature
CONT: continuity
⊣⊢: diode test

Configuring scan parameters

This section details how to select internal scanning and how to configure the scan parameters.

Front Panel

Use the SHIFT-CONFIG keys to select the scan type and configure the scan parameters.

1. Press SHIFT then CONFIG. The instrument will display the following prompt for internal scanning:

   TYPE: INT

   Use the ▲ or ▼ key if EXT is displayed. Then press ENTER.

2. The following message will be displayed:

   MIN CHAN: 1

   Use the ▲ and ▼ keys to select the channel at which the scanning will begin, then press ENTER.

3. The unit will then display the following message:

   MAX CHAN: 10

Use the ◀ . ▶ , ▲, and ▼ keys to select the channel at which the scanning will stop, then press ENTER.

4. The instrument will then display the following message:

   TIMER? OFF

   Use the ◀ or ▶ key to select the ON option if desired, then press ENTER. Select the scan time when prompted, then press ENTER:

   00H:00M:01.000S

5. The unit will then display the following message:

   RDG CNT: 0010

Use the ◀ . ▶ , ▲, and ▼ keys to select the desired number of readings of the selected list to be taken and stored by the instrument. Then press ENTER.

The instrument will store in memory the number of readings specified with RDG CNT. After the scanning has been completed, these readings can be accessed by pressing the RECALL key on the front panel and then using the ◀ . ▶ , ▲, and ▼ keys to scroll through the stored readings.

6. The following are the options to start the scanning:

STEP — Pressing the STEP key on the front panel will direct the instrument to begin scanning at Channel 1 and scan the number of channels specified with RDG CNT. It will store the same number of readings.

TRIG — Pressing the TRIG key on the front panel will direct the instrument to begin scanning at the present channel setting and scan the number of channels specified with RDG CNT. It will store the same number of readings.

SCAN — Pressing the SCAN key on the front panel will direct the instrument to scan through the channels specified with MIN CHAN and MAX CHAN and store the number of readings specified by RDG CNT.

7. Pressing EXIT will clear the current readings and reset the channel to Channel 1.

Remote interface

Use the :ROUTe:SCAN:LSELect command to select internal or external scanning. For example, to select internal scanning use the following command:

```
PRINT #1, "output 16; :route:scan:lselect internal"
```

If you have selected internal, use the following command to set the list of channels to be scanned:

```
PRINT #1, "output 16; :route:scan[:internal] (@scan list)"
```

For example, to scan channels 1 through 10 inclusively:

```
PRINT #1, "output 16; :route:scan[:internal] (@1:10)"
```

SCPI scanner commands

Table 3-1 summarizes commands that control scanner operations over the remote interface. For more detailed information on these and other bus commands, refer to the multimeter manuals.

The commands and comments in italics are valid only when the Model 2000-SCAN card is installed in a Model 2001 or Model 2002 Multimeter.

Table 3-1
Summary of SCPI scanner commands

Command	Description
:ROUTe	Route subsystem.
:CLOSE <list>	Close channels.
:STATe?	Return all closed channels.
:OPEN <*list*>|ALL	Open channels.
:ALL	Open any closed channels.
:MULTiple	Multiple channel commands:
:CLOSE <list>	Close specified channels (1 thru 11).
:STATe?	Query closed channels.
:OPEN <list>	Open specified channels.
:SCAN	Scanning commands.
[:INTernal] <scan list>	Program internal scan list.
:FUNCtion <list>,<function>	Program channel functions.
:EXTernal <scan list>	Program external scan list.
:LSELect NONE | INTernal | EXTernal	Select scan list.
[:SENSe[1]]	Sense subsystem
:FUNCTion <function list>	Select measurement function.
:ALTernate[1]	Program alternate function.
:SAVe	Save alternate function.
:RECall	Recall alternate function.
The INT or EXT <function> parameter is one of the following:	
VOLTage:DC	DC volts
VOLTage:AC	AC volts
TEMPerature	Temperature
FREQuency	Frequency
RESistance	2-wire resistance
FRESistance	4-wire resistance
RJUNctionX	Reference junction (X=1 to 5)
NONE	No function (skips listed channel during scan.)
ALTernate[1]	Alternate function

Notes:
1. The :ROUT:SCAN:LSEL command is coupled to the :ROUT:SCAN:INT command. When the :ROUT:SCAN:INT command is executed, the :ROUT:SCAN:LSEL parameter will be set to INTernal.
2. Upper-case letters indicate short form of commands.
3. Brackets indicate optional command and should not be used when sending commands to instrument.
4. When sending SCPI commands, be sure to include a space character between each command and parameter.

Model 2001/2002 front panel scanner controls and SCPI scanner commands

The following paragraphs give an overview of the various Model 2001/2002 front panel controls and corresponding SCPI commands use to control the Model 2000-SCAN scanner card when installed in a Model 2001/2002 Multimeter.

CAUTION ***Damage may occur because break-before-make operation for channels 5 and 10 cannot be guaranteed when the high-speed scanning modes of the Model 2001/2002 Multimeter are selected.***

Closing channels

Front panel

Use the front panel CHAN key to close specific channels as follows:

1. From normal display, press the CHAN key. The instrument will display the following menu:

   CHANNEL SELECTION
   CLOSE-CHANNEL OPEN-ALL-CHANNELS

2. Select CLOSE-CHANNEL, then press ENTER. The Model 2001/2002 will display the following prompt:

   ENTER CHANNEL# 00 (1-10)

3. Use the cursor and range keys to select the channel you wish to close (1-10), then press ENTER. Any previously closed channel will open, and the selected channel will close.

NOTE *Once a channel is closed, use the ◄ or ► key to manually scan through channels. Also, you can use the NEXT display to view three successive channels simultaneously.*

Remote interface

Use the :ROUT:CLOSE command to close the desired channel. For example, assume you wish to close channel 3. The following command would be used:

```
PRINT #1, "output 16; :rout:close (@3)"
```

Opening channels

Front panel

Use the front panel CHAN key to open any closed channels as follows:

1. Press the CHAN key. The instrument will display the following menu:

   CHANNEL SELECTION
   CLOSE-CHANNEL OPEN-ALL-CHANNELS

2. Select OPEN-ALL-CHANNELS, then press ENTER. The closed channel will open immediately.

Remote interface

Use the :ROUT:OPEN command to open the closed channel. For example, the following command would be used to open channel 3:

```
PRINT #1, "output 16; :rout:open (@3)"
```

(You can also use :ROUT:OPEN:ALL or :ROUT:OPEN ALL to open channels.)

Scanning channels

Scanner channels are scanned by configuring scan channels and programming the Model 2001 or 2002 to perform a scan. The following paragraphs outline step-by-step procedures for performing basic scanning from the front panel and over the IEEE-488 bus.

Front panel scanning

Step 1: Configure channels

Use CONFIG-CHAN to select the measurement functions for each of the scanner channels as follows:

1. Press CONFIG-CHAN. The instrument will display the following menu:

   CONFIGURE CHANNELS
   INTERNAL-CHANS EXTERNAL-INPUTS

2. Select INTERNAL-CHANS, then press ENTER. The multimeter will display the following menu:

   SET INTERNAL CHANS
   1=DCV 2=DCV 3=DCV 4=DCV 5=DCV

3. Using the cursor keys, select the desired channel (press the right cursor key to display channels 6 through 10).
4. Using the range keys, select the desired measurement function: DCV, ACV, Ω2W, Ω4W, FRQ, TMP, ALT, --- (None).
5. Repeat steps 3 and 4 for each of the channels you wish to scan. NOTE: Select --- (none) to omit a channel from the scan list.
6. After selecting all measurement functions, press ENTER.
7. Press EXIT to return to normal display.

Step 2: Configure and start scan

Configure the scan as follows:

1. Press CONFIG-SCAN. The Model 2001/2002 will display the following:

   SCAN OPERATION
   INTERNAL EXTERNAL

2. Select INTERNAL, then press ENTER.
3. Press SCAN, and follow the prompts to configure scanning. See the following paragraphs for details.

Using SCAN to configure scan parameters

Once the internal or external scan list is enabled, you use the SCAN key to configure scan count, scan interval, and enable buffer storage. The steps below outline the basic procedure for using the SCAN key to configure internal scanner operation.

1. From normal display, press CONFIG-SCAN. The instrument will display the following:

   SCAN OPERATION
   INTERNAL EXTERNAL
2. Select INTERNAL, then press ENTER.
3. Press SCAN. The unit will display the following message:

   SCAN COUNT = 00010
4. Using the range and cursor keys, select the number of scan sequences, then press ENTER. The instrument will display the following:

   USE SCAN TIMER?
   YES NO
5. If you do not wish to use the scan timer (interval between scans), select NO, then press ENTER, and go on to step 7. If you wish to use and program the interval between scans, select YES, then press EN-TER. The instrument will display the following:

   INTRVL = 000002.500
6. Using the range and cursor keys, select the desired interval between scan sequences, then press ENTER.
7. The instrument will then prompt you as to whether or not you wish to store data in the buffer as follows:

   DATA TO MEMORY?
   NO YES
8. To store scanned data in the buffer, select YES; otherwise choose NO, then press ENTER.
9. If you elected to store data in memory, the instrument will prompt you as follows:

   00100 RDGS TO BUFFER

   Press ENTER to continue.

NOTE *Use CONFIG-STORE to program the number of readings to store.*

10. Press ENTER to begin scanning at the following prompt:
11. Press ENTER to begin

    0010 scans of 10 channels
12. The instrument will then scan using selected scanning parameters. If you elected to store data in memory, the instrument will display the reading number on the bottom line of the display as readings are stored.
13. After readings are stored, the following will be displayed:

    SCAN COMPLETE
    RECALL-DATA SCAN-AGAIN EXIT
14. Select the desired operation, then press ENTER.

Remote interface scanning

Step 1: Program channel functions

Use :ROUT:SCAN:INT:FUNC to program functions for the selected channels. For example, assume that you want to measure DC volts on channel 1, AC volts on channel 2, and 2-wire resistance on channel 3. The commands to do so are as follows:

```
PRINT #1, "output 16; :rout:scan:int:func (@1),'volt:dc'"
PRINT #1, "otuput 16; :rout:scan:int:func (@2), 'volt:ac'"
PRINT #1, "output 16; :rout:scan:int:func (@3), 'res'"
```

If, on the other hand, you wish to use the same function (DCV, for example) on all three channels, a single command would suffice:

```
PRINT #1, "output 16; :rout:scan:int:func (@1,2,3), 'volt:dc'"
```

Step 2: Program internal scan list and start scan

Use the :ROUT:SCAN:INT command to program a scan list (channels you wish to scan). For example, assume that you wish to scan channels 1, 2, and 3. This scan list would be programmed as follows:

```
PRINT #1, "output 16; :rout:scan:int (@1,2,3)"
```

Scanning will begin immediately when this command is sent.

To disable scanning, send the :ROUT:SCAN:LSEL NONE command:

```
PRINT #1, "output 16; :rout:scan:lsel none"
```

NOTE *The :ABORT command will abort the present scan in progress and reset the channel list to the beginning. Depending on various trigger layer parameters, :ABORT may also stop the scanning process.*

Using the scanner with the buffer

The Model 2001 internal buffer can be used to store readings taken while using the scanner. The following paragraphs outline the steps necessary for fundamental data storage of scanner readings.

Step 1: Configure channel

1. Press CONFIG-CHAN. The instrument will display the following:

   CONFIGURE CHANNEL
   INTERNAL-CHANS EXTERNAL-INPUTS

2. Select INTERNAL-CHANS. The Model 2001/2002 will display the following:

   SET INTERNAL CHANNELS
   1=DCV 2=DCV 3=DCV 4=DCV 5=DCV

3. Use the cursor and range keys to select channels and functions, then press ENTER when you have set all functions.
4. Press EXIT to return to normal display.

Step 2: Configure buffer

1. Press CONFIG-STORE. The unit will display the following:

   CONFIG DATA STORE
   BURST-MODE DATA GROUP CONTROL
   CLEAR-ALL COUNT FEED

2. Select COUNT, then press ENTER. The instrument will display the following:

   SET BUFFER SIZE
   ENTER-COUNT USE-TRIGGER-MODEL

3. Select ENTER-COUNT and press ENTER to view the following:

   BUFFER SIZE = 00010

4. Using the cursor and range keys, select the number of readings to store. Usually, this number will be the same as the number of channels you are scanning. For example, if you are using all 10 scanner channels, select 10 readings.
5. Press ENTER to complete programming data storage; then EXIT to return to normal display.

Step 3: Configure scan, perform scan, and recall readings

1. From normal display, press CONFIG-SCAN. The instrument will display the following:

   SCAN OPERATION
   INTERNAL EXTERNAL

2. Select INTERNAL, then press ENTER.
3. Press SCAN, then follow the prompts. See "Configuring scan parameters".

RTD temperature measurements

RTD temperature measurements are possible when the Model 2000-SCAN card is installed in the Model 2001 or Model 2002 Multimeter. The following paragraphs outline the procedures for making temperature measurements from the front panel using the scanner. For more detailed information on temperature measurements in general, refer to the multimeter manuals.

Step 1: Connect RTD probes

Connect RTD probes to the scanner using the basic resistance connections outlined in the multimeter manual. For 4-wire probes, pair the connections as follows:

- Channels 1 and 6: probe #1
- Channels 2 and 7: probe #2
- Channels 3 and 8: probe #3
- Channels 4 and 9: probe #4
- Channels 5 and 10: probe #5

Step 2: Select sensor type and units

1. From normal display, press CONFIG-TEMP. The instrument will display the following:

   CONFIG TEMPERATURE
   SENSOR UNITS SPEED FILTER RESLN

2. Select SENSOR, then press ENTER. The following will be displayed:

   TEMP SENSOR TYPE
   RTD 4-WIRE-RTD THERMOCOUPLE

3. Select RTD or 4-WIRE-RTD as appropriate for the sensor type you are using, then press ENTER. The instrument will display the following:

   SET RTD TYPE
   PT385 PT3916 USER-RTD

4. Select the RTD type from among the displayed types, then press ENTER.
5. Press EXIT to return to the CONFIG TEMPERATURE menu.
6. Select UNITS, then press ENTER. The unit will display the following selections:

   SET TEMP UNITS
   DEG-C DEG-F K

7. Choose the type of temperature units you desire to use: °F, °C, or K, then press ENTER.
8. Before exiting the temperature configuration menu, select speed, filter, and resolution operating modes, if desired.
9. Press EXIT to return to normal display.

Step 3: Configure channels

10. Press CONFIG-CHAN. The instrument will display the following:

    CONFIGURE CHANNELS
    INTERNAL-CHANS EXTERNAL-INPUTS

11. Select INTERNAL-CHANS. The Model 2001 will display the following:

    SET INTERNAL CHANNELS
    1=DCV 2=DCV 3=DCV 4=DCV 5=DCV

12. Use the cursor and range keys to select channels and functions. Set the function type to TMP for all channels connected to RTD probes. Select --- (none) for channels without probes connected.
13. Press ENTER to return to normal display.

Step 4: Configure scan and scan channels

1. From normal display, press CONFIG-SCAN. The instrument will display the following:

   SCAN OPERATION
   INTERNAL EXTERNAL

2. Select INTERNAL, then press ENTER.
3. Press SCAN, then follow the prompts.

Typical applications

Resistor testing

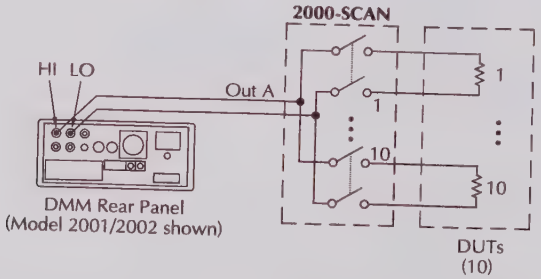
The Model 2000-SCAN can be used to test up to 10 resistors using 2-wire measurements, or up to five resistors using 4-wire measurements. Such tests use the Model 2000 Ω2 and Ω4 resistance functions.

2-wire resistance tests

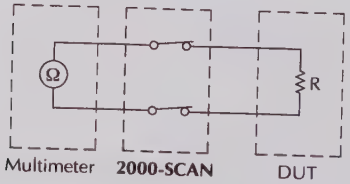
Figure 3-1 shows a typical test setup for making 2-wire resistance measurements. The Model 2000-SCAN card provides the switching function, while the resistance measurements are made by a Model 2000 Multimeter. Since only 2-pole switching is required for this application, one Model 2000-SCAN card can be used to switch up to 10 resistors.

Measurement accuracy can be optimized by minimizing residual resistance: make connecting wires as short as possible and limit the number of connectors to minimize path resistance. Another technique is to short one of the scanner channel inputs, close the shorted channel, and then enable the multimeter REL feature to null out path resistance. Leave REL enabled for the entire test.

Figure 3-1
2-wire resistance test connections



A. Test Configuration

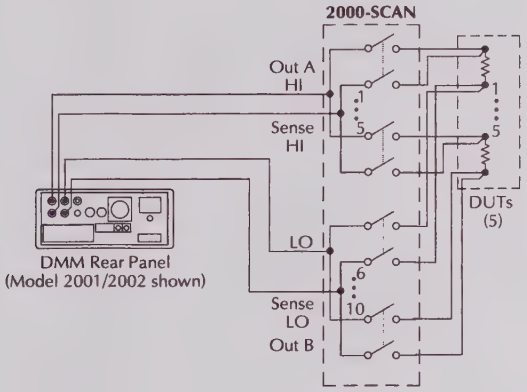


B. Simplified Equivalent Circuit

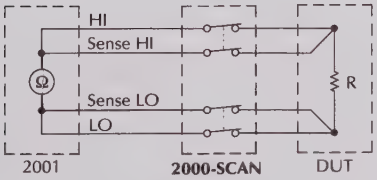
4-wire resistance tests

More precise measurements over a wider range of system and DUT conditions can be obtained by using the 4-wire measurement scheme shown in Figure 3-2. Here, separate sense leads from the Model 2000 Multimeter are routed through the scanner to the resistor under test. The extra set of sense leads minimizes the effects of voltage drops across the test leads, greatly reducing measurement errors with lower DUT resistances. Note, however, that an extra two poles of switching are required for each resistor tested. For this reason, only five resistors can be tested using this configuration.

Figure 3-2
4-wire resistance test connections



A. Test Configuration



B. Simplified Equivalent Circuit

Combining 2-pole and 4-pole switching (Models 2001/2002)

The Model 2000-SCAN can combine 2- and 4-pole switching in various combinations. For example, you might require 4-pole switching for only two resistors, while the remaining resistors could be tested using conventional 2-pole switching.

Figure 3-3 shows a test configuration using mixed 2-pole and 4-pole switching. Four-pole switching is used only for device 1 (connected to channels 1 and 6) and device 2 (connected to channels 2 and 7). Six more resistors are tested using 2-pole switching.

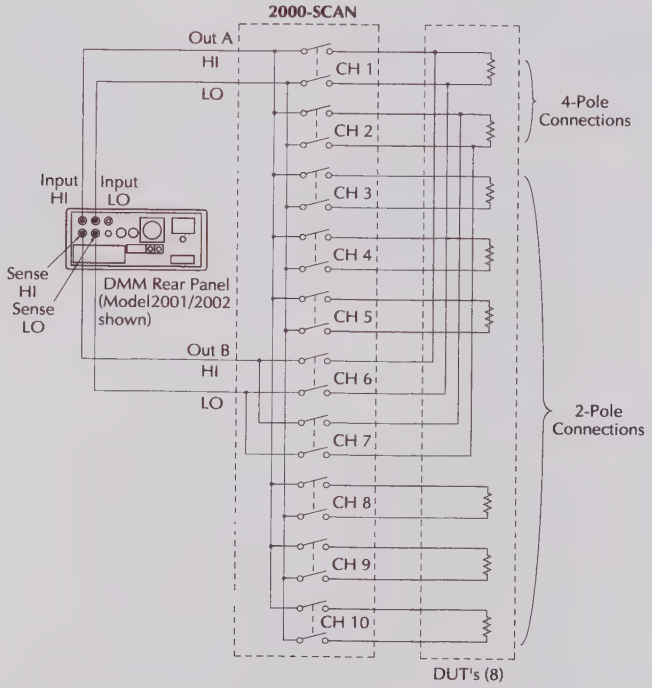


Figure 3-3
Combining 2-pole and 4-pole switching (Model 2001/2002)

Measurement functions for each scanner channel are defined using the INTERNAL-CHANS menu available by pressing CONFIG-CHAN (see "Using the scanner with the buffer"). Measurement functions for this test would be set up as follows:

Channels 1 and 2: Ω4W

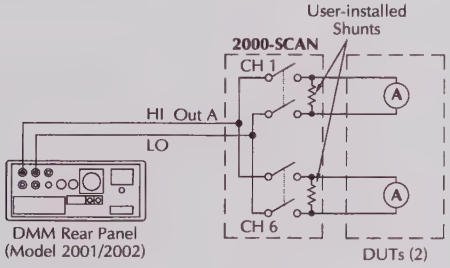
Channels 3, 4, 5 and 8, 10: Ω2W

Note that functions cannot be defined for channels 6 and 7 with this application because these channels are paired with channels 1 and 2 for 4-pole switching.

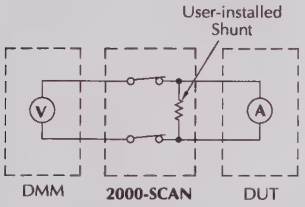
Current measurements

Although the Model 2000-SCAN is not intended for direct current measurements, on-card shunt resistors can be installed for channels 1 and 6 to allow for indirect current measurements. Figure 3-4 shows the typical configuration for current measurements. Refer to Section 2 of this manual for specific information on recommended shunt resistors and their installation.

Figure 3-4
Connections for current measurements



A. Test Configuration



B. Simplified Equivalent Circuit

The current through each shunt resistor can be calculated as follows:

Where: I = current being determined
V = voltage measured by multimeter
R = shunt resistance value

Instead of manually calculating current, set up a Model 2000/2001/2002 mX + b math calculation function. (Here, m = 1/R and b = 0.). The multimeter will then display the actual current value. Refer to the multimeter Manuals for details on using math functions.

Measurement considerations

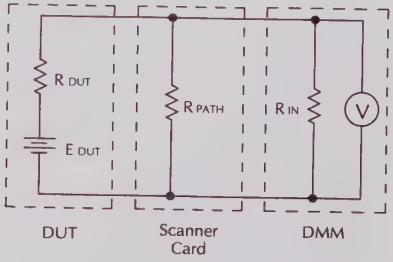
Many measurements made with the Model 2000-SCAN are subject to various effects that can seriously affect low-level measurement accuracy. The following paragraphs discuss these effects and ways to minimize them.

Path isolation

The path isolation is simply the equivalent impedance between any two test paths in a measurement system. Ideally, the path isolation should be infinite, but the actual resistance and distributed capacitance of cables and connectors results in less than infinite path isolation values for these devices.

Path isolation resistance forms a signal path that is in parallel with the equivalent resistance of the DUT, as shown in Figure 3-5. For low-to-medium device resistance values, path isolation resistance is seldom a consideration; however, it can seriously degrade measurement accuracy when testing high-impedance devices. The voltage measured across such a device, for example, can be substantially attenuated by the voltage divider action of the device source resistance and path isolation resistance, as shown in Figure 3-6. Also, leakage currents can be generated through these resistances by voltage sources in the system.

Figure 3-5
Path isolation resistance



R_{DUT} = Source Resistance of DUT
E_{DUT} = Source EMF of DUT
R_{PATH} = Path Isolation Resistance
R_{IN} = Input Resistance of Multimeter

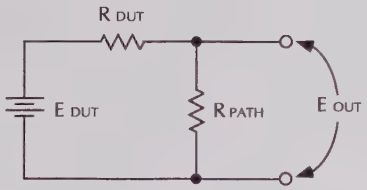


Figure 3-6
Voltage attenuation by path isolation resistance

$$E_{OUT} = \frac{E_{DUT} R_{PATH}}{R_{DUT} + R_{PATH}}$$

Magnetic fields

When a conductor cuts through magnetic lines of force, a very small current is generated. This phenomenon will frequently cause unwanted signals to occur in the test leads of a scanning system. If the conductor has sufficient length, even weak magnetic fields like those of the earth can create sufficient signals to affect low-level measurements. Two ways to reduce these effects are: (1) reduce the lengths of the test leads, and (2) minimize the exposed circuit area. In extreme cases, magnetic shielding may be required. Special metal with high permeability at low flux densities (such as mu metal) is effective at reducing these effects.

Even when the conductor is stationary, magnetically-induced signals may still be a problem. Fields can be produced by various signals such as the AC power line voltage. Large inductors such as power transformers can generate substantial magnetic fields, so care must be taken to keep the switching and measuring circuits a good distance away from these potential noise sources. At high current levels, even a single conductor can generate significant fields. These effects can be minimized by using twisted pairs, which will cancel out most of the resulting fields.

Electromagnetic interference (EMI)

The electromagnetic interference characteristics of the Model 2000 Multimeter comply with the electromagnetic compatibility (EMC) requirements of the European Union (EU) directives as denoted by the CE mark. However, it is still possible for sensitive measurements to be affected by external sources. In these instances, special precautions may be required in the test setup.

Sources of EMI include:

- Radio and television broadcast transmitters.
- Communications transmitters, including cellular phones and hand-held radios.
- Devices incorporating microprocessors and high-speed digital circuits.
- Impulse sources as in the case of arcing in high-voltage environments.

The instrument, measurement leads, and other cables should be kept as far away as possible from any EMI sources. Shielding measurement leads and the multimeter may reduce EMI to acceptable levels. In extreme cases, a specially constructed screen room may be required to sufficiently attenuate troublesome signals.

Many instruments incorporate internal filtering that may help reduce EMI effects. In some cases, additional external filtering may be required. Keep in mind, however, that filtering may have detrimental effects on the measurement.

Ground loops

When two or more instruments are connected together, care must be taken to avoid unwanted signals caused by ground loops. Ground loops usually occur when sensitive instrumentation is connected to other instrumentation with more than one signal return path such as power line ground. As shown in Figure 3-7, the resulting ground loop causes current to flow through the instrument LO signal leads and then back through power line ground. This circulating current develops a small but undesirable voltage between the LO terminals of the two instruments. This voltage will be added to the source voltage, affecting the accuracy of the measurement.

Figure 3-7
Power line ground loops

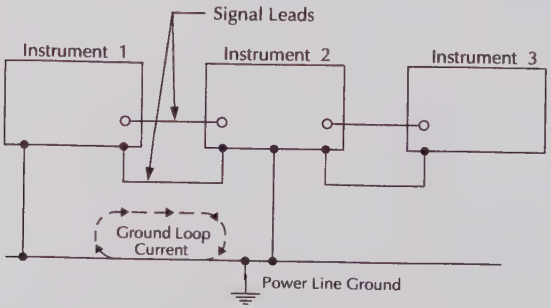


Figure 3-8 shows how to connect several instruments together to eliminate this type of ground loop problem. Here, only one instrument is connected to power line ground. Ground loops are not normally a problem with instruments having isolated LO terminals. However, all instru-

ments in the test setup may not be de-signed in this manner. When in doubt, consult the manual for all instrumentation in the test setup.

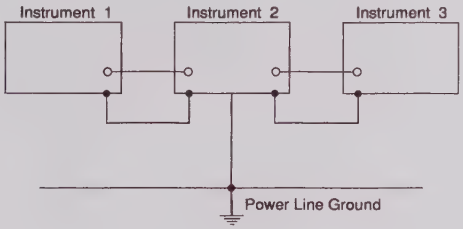


Figure 3-8
Eliminating ground loops

Keeping connectors clean

As is the case with any high-resistance device, the integrity of connectors can be compromised if they are not handled properly. If connector insulation becomes contaminated, the insulation resistance will be substantially reduced, affecting high-impedance measurement paths. Oils and salts from the skin can contaminate connector insulators, reducing their resistance. Also, contaminants present in the air can be deposited on the insulator surface. To avoid these problems, never touch the connector insulating material. In addition, the scanner card should be used only in clean, dry environments to avoid contamination.

If the connector insulators should become contaminated, either by inadvertent touching, or from air-borne deposits, they can be cleaned with a cotton swab dipped in clean methanol. After thoroughly cleaning, they should be allowed to dry for several hours in a low-humidity environment before use, or they can be dried more quickly using dry nitrogen.

4
Service Information

WARNING ***The information in this section is intended only for qualified service personnel. Some of the procedures may expose you to hazardous voltages that could result in personal injury or death. Do not attempt to perform these procedures unless you are qualified to do so.***

Introduction

This section contains information necessary to service the Model 2000-SCAN scanner card and is arranged as follows:

Handling and cleaning precautions — Discusses handling precautions and methods to clean the card should it become contaminated.

Performance verification — Covers the procedures necessary to determine if the scanner card meets stated specifications.

Special handling of static-sensitive devices — Reviews precautions necessary when handling static-sensitive devices.

Principles of operation — Briefly discusses circuit operation.

Troubleshooting — Presents some troubleshooting tips for the Model 2000-SCAN including relay replacement precautions.

Handling and cleaning precautions

Because of the high-impedance areas on the Model 2000-SCAN, care should be taken when handling or servicing the card to prevent possible contamination. The following precautions should be observed when servicing the card.

Handling precautions

- Handle the card only by the edges and shields.
- Do not touch any board surfaces or components not associated with the repair.
- Do not touch areas adjacent to electrical contacts.
- When servicing the card, wear clean cotton gloves.
- Do not store or operate the card in an environment where dust could settle on the circuit board.
- Use dry nitrogen gas to clean dust off the board if necessary.

Soldering precautions

Should it become necessary to use solder on the circuit board, observe the following precautions:

- Use an OA-based (organic activated) flux, and take care not to spread the flux to other areas of the circuit board.
- Remove the flux from the work areas when the repair has been completed. Use pure water along with clean cotton swabs or a clean, soft brush to re-move the flux.
- Once the flux has been removed, swab only the repaired area with methanol, then blow dry the board with dry nitrogen gas.
- After cleaning, the card should be allowed to dry in a 50°C low-humidity environment for several hours before use.

Performance verification

The following paragraphs discuss performance verification procedures for the Model 2000-SCAN, including path resistance, contact potential, and isolation.

NOTE *Contamination will degrade the performance of the card. To avoid contamination, always grasp the card by the side edges and covers. Do not touch connector insulators, board surfaces, or components.*

Failure of any performance verification test may indicate that the scanner card is contaminated. See Section 4 "Handling and cleaning precautions" for information on cleaning the card.

Environmental conditions

All verification measurements should be made at an ambient temperature between 18° and 28°C, and at a relative humidity of less than 70%.

Recommended equipment

Table 4-1 summarizes the equipment necessary for performance verification, along with an application for each item.

Scanner card connections

Jumper wires or connecting cables can simply be hard-wired directly to the screw terminals of the Model 2000-SCAN. Detailed connection information is provided in Section 2.

Table 4-1
Recommended verification equipment

Description	Model/part	Specifications	Application
Multimeter	Keithley 2001	20Ω; 72ppm	Control card, measure path resistance
Electrometer with voltage source	Keithley 617	10pA, 100pA; 1.6% 100V source; 0.2%	Path isolation
Sensitive Digital Voltmeter	Keithley 182	3mV; 60ppm	Contact potential
Triax cable (unterminated)	Keithley 7025	—	Path isolation
Low-thermal cable	Keithley 1484	—	Contact potential
#22AWG solid copper wire	—	—	Path resistance
#22AWG Teflon-insulated stranded wire	—	—	Path isolation

Path resistance tests

Perform the following steps to verify that the path resistance of each channel is with specified values.

1. Connect the HI and LO terminals of all 10 channel inputs together to make one common terminal using #22AWG solid copper jumper wires (see Figure 4-1).

NOTE *Make sure that all jumper wires are clean and free of oxides.*

2. Connect the output cables to OUT A HI and LO, as shown in Figure 4-1.
3. With the power off, install the scanner card in the Model 2001 Multimeter.
4. Turn on the Model 2001, and allow it to warm up for one hour before proceeding.
5. Select the Ω2W function and the 20Ω range on the Model 2001.
6. Temporarily connect a second set of output leads, identical in length and type to the leads connected to the scanner card output, to the Model 2001 rear panel HI and LO INPUT jacks. Be sure to select the rear panel terminals with the front panel INPUT switch.
7. Short the free ends of the temporary leads together, and allow the reading to settle. Enable the Model 2001 REL mode after settling, and leave REL enabled for the remainder of the path resistance tests.
8. Disconnect the temporary leads from the multimeter, and connect the output leads from the scanner card to the rear panel HI and LO INPUT jacks (see Figure 4-1).
9. Close channel 1 as follows;
   A. From normal display, press CHAN. The instrument will display the following:
      CHANNEL SELECTION
      CLOSE-CHANNEL OPEN-ALL-CHANNELS
   B. Select CLOSE-CHANNEL, then press ENTER. The Model 2001 will display the following:
      ENTER CHAN#01 (1-10)
   C. Using the range and cursor keys, select channel 01, then press ENTER.
   D. Press EXIT to return to normal display.

10. Note the resistance reading on the Model 2001. Verify that the reading is <2Ω.
11. Repeat steps 9 and 10 for channels 2-9. Verify that the path resistance for each channel is as follows:

    channels 1-10: <2Ω.

12. After completing the tests, turn off the Model 2001 power, remove the scanner card, and remove all jumper wires (leave HI and LO shorted for each channel if you intend to perform contact potential tests).

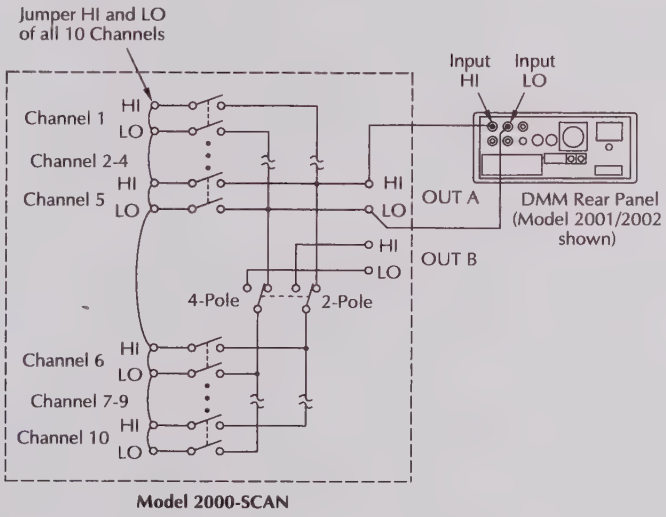


Figure 4-1
Connections for path resistance checks

Contact potential tests

These tests check the EMF (contact potential) generated by each relay contact pair (HI and LO) for each channel. The tests use a sensitive digital voltmeter (Model 182) to measure the contact potential.

Perform the following procedure to check contact potential of each channel.

1. Connect 1" #22AWG copper jumper wires between the HI and LO terminals of each channel input (see Figure 4-2).
2. Connect the Model 182 to OUT A HI and LO using the low-thermal cable (see Figure 4-2).
3. With the power off, install the scanner card in the Model 2001 Multimeter.
4. Turn on the Model 2001 and the Model 182 Sensitive Digital Voltmeter. Allow the Model 182 to warm up for two hours before measurement.
5. Select the 3mV range on the Model 182.
6. Select the DCV function on the Model 2001.
7. Using the CHAN key, close channel 1 (see Section 4 "Path resistance tests" for procedure).
8. Verify that the Model 182 reading is <1µV.
9. Repeat steps 7 and 8 for all 10 channels.
10. After completing all measurements, turn off the Model 2001 power, remove the scanner card, and disconnect all jumpers and test leads.

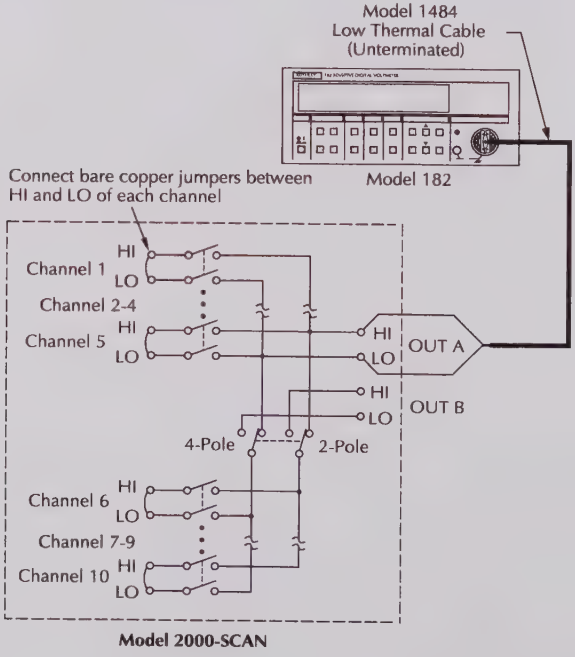


Figure 4-2
Connections for contact potential tests

Isolation tests

These tests check the leakage resistance (isolation) between all HI and LO terminals and from HI and LO terminals to chassis ground. In general, the test is performed by applying a voltage (100V) across the terminals and then measuring the leakage current. The isolation resistance is then calculated as R = V/I. In the following procedure, the Model 617 functions as a voltage source and as an ammeter. In the V/I function, the Model 617 internally calculates the resistance from the known voltage and current levels, and displays the resistance value.

Perform the following steps to check isolation:

1. Connect a 4" length of Teflon-insulated #22AWG stranded wire to every HI and LO terminal on the scanner card (both inputs and outputs). Mark the free end of each wire so you can identify wires when the scanner card is installed.
2. With the power off, install the scanner card in the multimeter.
3. Turn on the Model 2001 power.
4. Turn on the Model 617, and allow the unit to warm up for two hours for rated accuracy.
5. Select the Model 617 2pA range, and enable zero check and zero correct in that order. Leave zero correct enabled for the entire procedure.

WARNING ***The following steps use high voltage (100V). Be sure to remove power from the circuit before making connection changes.***

6. Set the Model 617 voltage source for +100V, and select the 200nA current range. Make sure the voltage source is still in standby.
7. Place the Model 617 in the V/I measurement function by pressing SHIFT OHMS.
8. With the Model 617 in standby, connect the electrometer to OUT A HI and LO terminals of the scanner card, as shown in Figure 4-3.

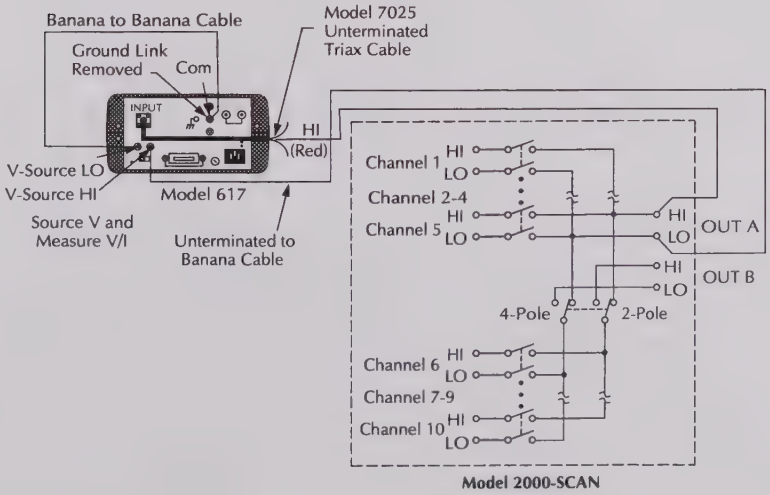


Figure 4-3
Connections for same-channel isolation tests

9. Close channel 1 using the CHAN key (see Section 4 "Path resistance tests" for details).
10. On the Model 617, disable zero check, and press OPERATE to source 100V.
11. After allowing the reading on the Model 617 to settle, verify that the reading is >1GΩ ($10^9\Omega$). This measurement represents the isolation resistance between the HI and LO terminals of channel 1.
12. Place the Model 617 in standby, and enable zero check.
13. Repeat steps 9 through 12 for channels 2 through 10. Be sure that the channel under test is closed.
14. With the Model 617 voltage source in standby, connect the electrometer to the HI terminals of scanner card channels 1 and 2, as shown in Figure 4-4.

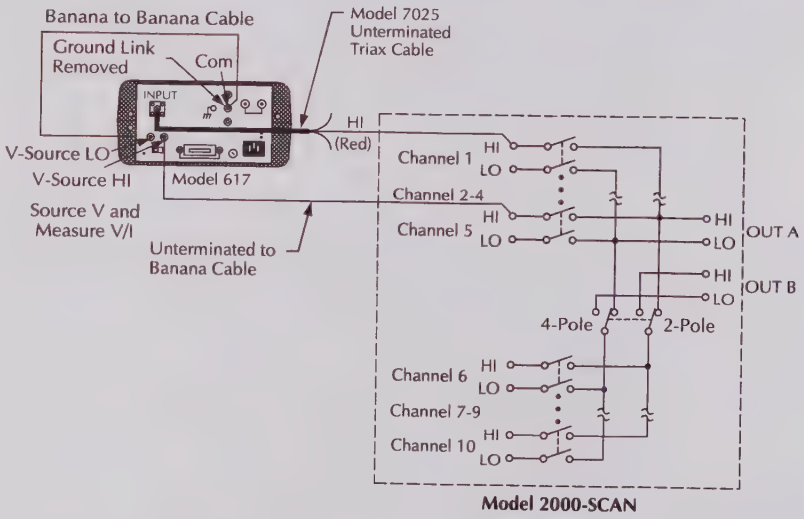


Figure 4-4
Connections for channel-to-channel isolation tests

15. Close channel 1 using the CHAN key.
16. On the Model 617, disable zero check, and press OPERATE to source 100V.
17. After allowing the reading on the Model 617 to settle, verify that the reading is >1GΩ ($10^9\Omega$). This measurement represents the isolation resistance between the HI terminals of channels 1 and 2.
18. Place the Model 617 in standby, and enable zero check.
19. Repeat steps 14 through 18 to measure isolation resistance between the channel 1 HI terminal and channels 3 through 10 HI terminals. Be sure that the electrometer is connected to the HI terminals of the two channels being tested, and that channel 1 is closed.
20. Repeat steps 14 through 19 for the LO terminals of channels 1 through 10. Be sure the electrometer is connected to the LO terminals of the two channels being tested, and that channel 1 is closed.

21. With the electrometer voltage source in standby, connect the electrometer to channel 1 HI and chassis ground, as shown in Figure 4-5.

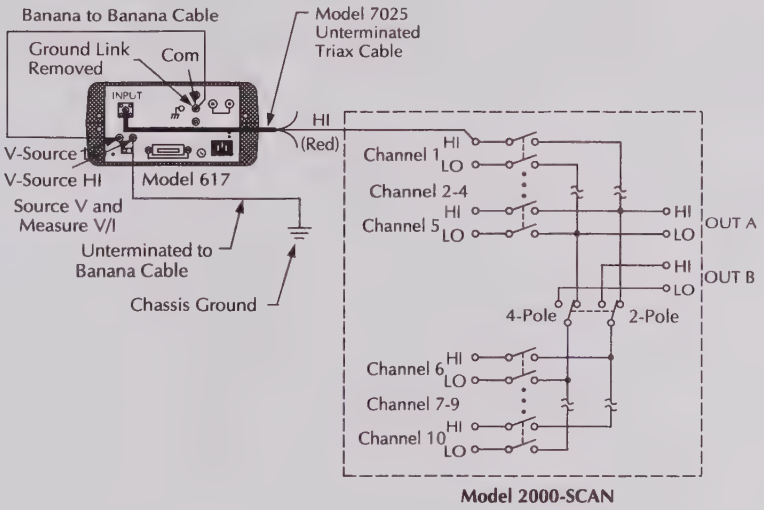


Figure 4-5
Connections for HI and LO terminal to chassis ground isolation tests

22. Program the Model 2000 to close channel 1.
23. On the Model 617, disable zero check, and press OPERATE to source +100V.
24. After allowing the reading on the Model 617 to settle, verify that it is >1GΩ ($10^9\Omega$).
25. Put the electrometer in standby, and enable zero check.
26. Repeat steps 21 through 25 for channels 2 through 10. One electrometer lead should be connected to the HI terminal of the channel being testing, and the other lead should be connected to chassis ground.
27. Repeat steps 21 through 26 for channels 1 through 10 LO terminals. One electrometer lead should be connected to the LO terminal of the channel being tested, and the other lead should be connected to chassis ground. In addition, channel 1 should be closed.

Special handling of static-sensitive devices

CMOS and other high-impedance devices are subject to possible static discharge damage because of the high-impedance levels involved. When handling such devices, use the precautions listed below.

NOTE *In order to prevent damage, assume that all parts are static-sensitive.*

1. Such devices should be transported and handled only in containers specially designed to prevent or dissipate static build-up. Typically, these devices will be received in anti-static containers made of plastic or foam. Keep these parts in their original containers until ready for installation or use.
2. Remove the devices from their protective containers only at a properly grounded workstation. Also, ground yourself with an appropriate wrist strap while working with these devices.
3. Handle the devices only by the body; do not touch the pins or terminals.
4. Any printed circuit board into which the device is to be inserted must first be grounded to the bench or table.
5. Use only anti-static type de-soldering tools and grounded-tip soldering irons.

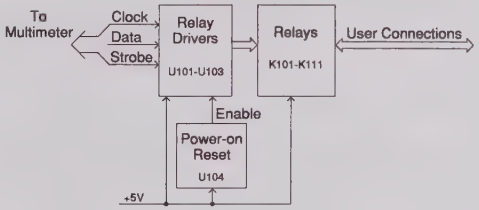
Principles of operation

The following paragraphs discuss the basic operating principles for the Model 2000-SCAN, and can be used as an aid in troubleshooting the card. The schematic drawing of the card is shown on drawing number 2000-176, located at the end of Section 5 of this manual.

Block diagram

Figure 4-6 shows a simplified block diagram of the Model 2000-SCAN. Key elements include the relay drivers and relays, as well as the power-up reset circuit. These various elements are discussed in the following paragraphs.

Figure 4-6
Block diagram



Relay control

Card relays are controlled by serial data transmitted via the relay DATA line. A total of three bytes are shifted in serial fashion into latches located in the card relay driver ICs. The serial data is clocked in by the CLOCK line. As data overflows one register, it is fed out the Q'S line of the register down the chain.

Once all three bytes have shifted into the card, the STROBE line is set high to latch the relay information into the Q outputs of the relay drivers, and the appropriate relays are energized (assuming the driver outputs are enabled, as discussed below). Note that a relay driver output goes low to energize the corresponding relay.

Switching circuits

Relays K101 through K106 and K108 to K111 perform input switching, while K107 configures the card for 2-pole or 4-pole operation.

Power-on safeguard

A power-on safeguard circuit, made up of U104 and associated components, ensures that relays do not change state on power-up and power-down. This circuit disables all relay actuation during power-up and power-down periods by holding the OE (output enable lines) high during these periods.

Troubleshooting

Troubleshooting equipment

Table 4-2 summarizes recommended equipment for troubleshooting the Model 2000-SCAN.

Table 4-2
Recommended troubleshooting equipment

Description	Manufacturer and model	Application
Multimeter	Keithley 2000/2001	DCV checks
Oscilloscope	TEK 2243	View logic waveforms

Troubleshooting access

In order to gain access to the scanner card circuit board to measure voltages under actual operating conditions, perform the following steps:

1. Turn off the Model 2000 power, and disconnect the line cord and all other equipment.
2. If wires are connected to the scanner card, remove the scanner card from the multimeter.
3. Remove the Model 2000 cover as follows:
   A. Remove the handle by rotating it to align the arrows on the handle mounting ears. Pull out and remove the handle.
   B. Remove the screws that secure the handle mounting ears, then remove the ears.
   C. Remove the screws that attach the rear bezel to the case, then remove the bezel.
   D. Remove the bottom screws that grounds the case to the chassis.

WARNING ***Be sure to install and tighten the grounding screws after replacing the cover.***

   E. Remove the cover by pulling it off towards the rear.
4. Disconnect any wires connected to the scanner card terminal blocks.
5. Install the scanner card in the multimeter.
6. Connect the line cord, and turn on the power to measure voltages (see following paragraph).

Troubleshooting procedure

Table 4-3 summarizes scanner card troubleshooting steps. Refer to the schematic diagram and component layout drawings at the end of Section 5 for component locations.

WARNING ***Lethal voltages are present within the Model 2000. Some of the procedures may expose you to hazardous voltages. Observe standard safety precautions for dealing with live circuits. Failure to do so could result in personal injury or death.***

CAUTION ***Use care when removing relays from the PC board to avoid pulling traces away from the circuit board. Before attempting to remove a relay, use an appropriate de-soldering tool, such as a solder sucker, to clear each mounting hole completely free of solder. Each relay pin must be free to move in its mounting hole before removal. Also, make certain that no burrs are present on the ends of the relay pins.***

NOTE *To avoid contamination, which could degrade card performance, always handle the card only by the side edges and covers. Do not touch edge connectors, board surfaces, or components on the card. Also, do not touch areas adjacent to electrical contacts on connectors.*

Table 4-3
Troubleshooting procedure

Step	Item/component	Required condition	Comments
1	Digital ground P1034, pin 1, 3, 5		All voltages referenced to digital ground.
2	P1034, pin 9	+5VDC	Card power supply voltage.
3	U101, pin 2	CLOCK pulses	Serial clock pulses.
4	U101, pin 3	DATA pulses	Serial data pulses.
5	U101, pin 7	STROBE pulse	End of relay update sequence.
6	U101-U103, pins 10-18	Low when relay state is changed.	High when relay is not changing state. Relay driver outputs.

5
Replaceable Parts

Introduction

This section contains replacement parts information, schematic diagram, and component layout drawing for the Model 2000-SCAN.

Parts list

A parts list for the scanner card is included in a table integrated with schematic diagram and component layout drawing for the board. Parts are listed alphabetically in order of circuit designation.

Ordering information

To place an order, or to obtain information concerning replacement parts, contact your Keithley representative or the factory (see inside front cover for addresses). When ordering parts, be sure to include the following information:

- Card model number (2000-SCAN)
- Card serial number
- Part description
- Circuit description, if applicable
- Keithley part number

Factory service

If the card is to be returned to Keithley Instruments for repair, perform the following:

- Call the Instruments Division Repair Department at 1-800-552-1115 for a Return Material Authorization (RMA) number.
- Complete the service form at the back of this manual and include it with the card.
- Carefully pack the card in the original packing carton.
- Write ATTENTION REPAIR DEPT and the RMA number on the shipping label.

NOTE *It is not necessary to return the Model 2000 Multimeter with the card.*

Component layout and schematic diagram

A component layout drawing and schematic diagram are included on the following pages integrated with the parts list for the Model 2000-SCAN.

Model 2000-SCAN, parts list

Circuit desig.	Description	Keithley part no.
	Card Ejector	FA-237
	Clip, Strain Relief	2001-351
	Shield, Scanner Bottom	2001-341
	Shield, Scanner Top	2001-342
	Sleeved Banana Plug Test Lead	CA-109
	Strain Relief, Bottom	2001-344
	Strain Relief, Top	2001-349
	Strip, Polyurethane	2001-345-1
C101-103, 105, 106	CAP, .1UF,20%,50V, CERAMIC	C-365-.1
C107	CAP, 100UF, 20%, 25V, ALUM ELEC	C-413-100
J1035,1036	CONN, FEMALE, 12 PIN	CS-768-12
K101-111	RELAY, MINATURE (DPDT) TQ2E-L2-5V	RL-155
P1034	CONN, FEMALE DUAL 16-PIN	CS-455
R134	RES, 1K, 5%, 1/4W, COMPOSITION OR FILM	R-76-1K
R147	RES, 4.7K, 5%, 1/4W, COMPOSITION OR FILM	R-76-4.7K
U101-103	IC, 8-BIT SERIAL-IN LATCH DRIVER, 5841A	IC-536
U104	IC, SUPPLY VOLTAGE SUPERVISOR, TL7705AC	IC-602

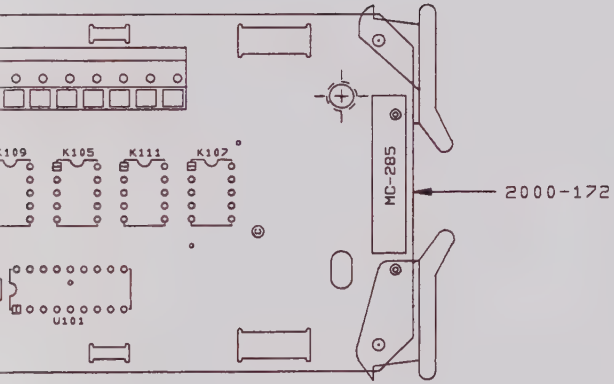
NO. 2000-170

* DO NOT INSTALL R145 A

DO NOT SCALE TH

KEITHLEY KEITHLEY
CLEVELAND

LTR.	ECO NO.	REVISION	ENG.	DATE
A	16777	RELEASED	SZ	4-30-94
A1	17051	REMOVED BAR CODE LABEL MC-612 -01 SIDE		8-14-95

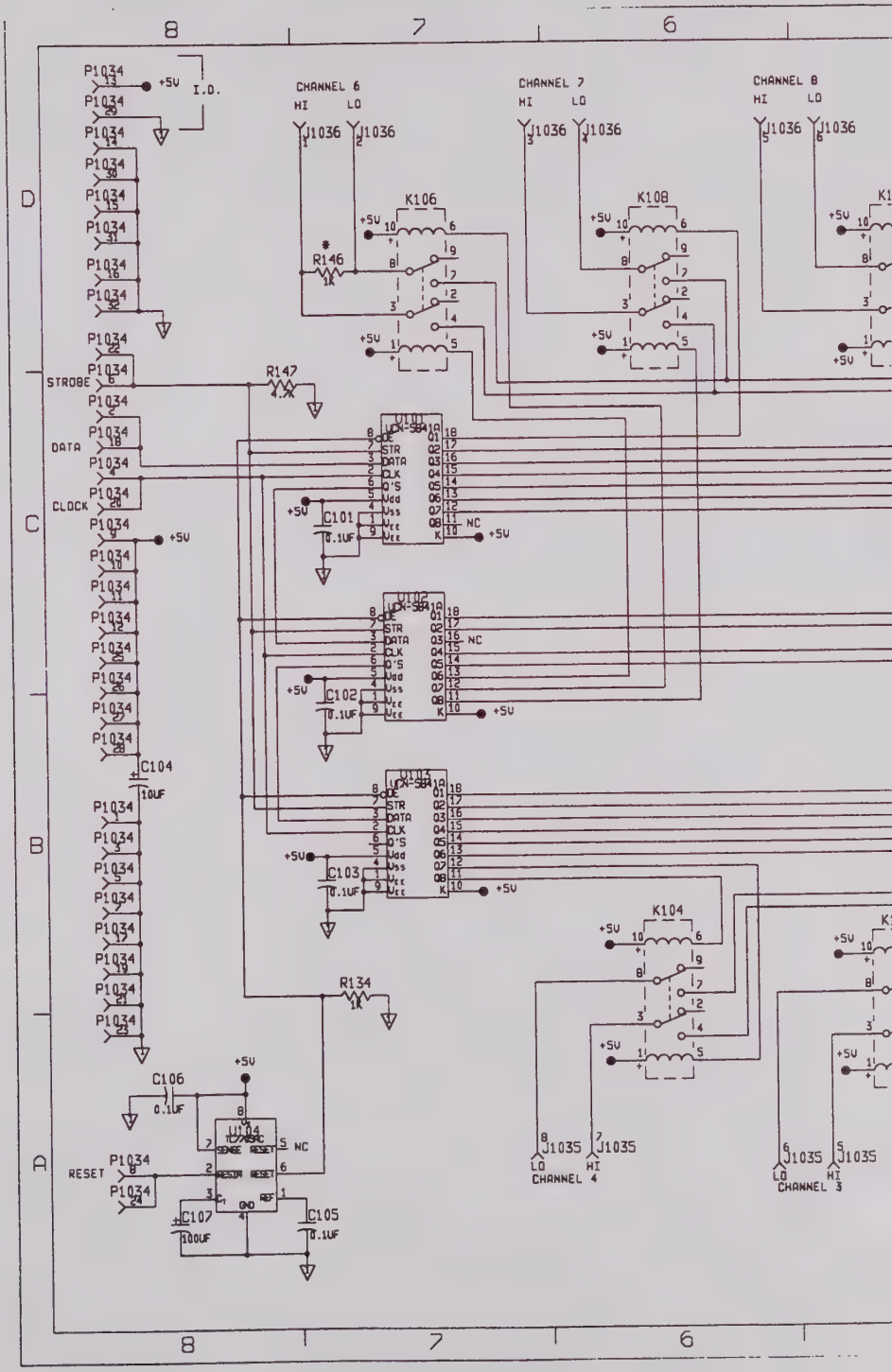


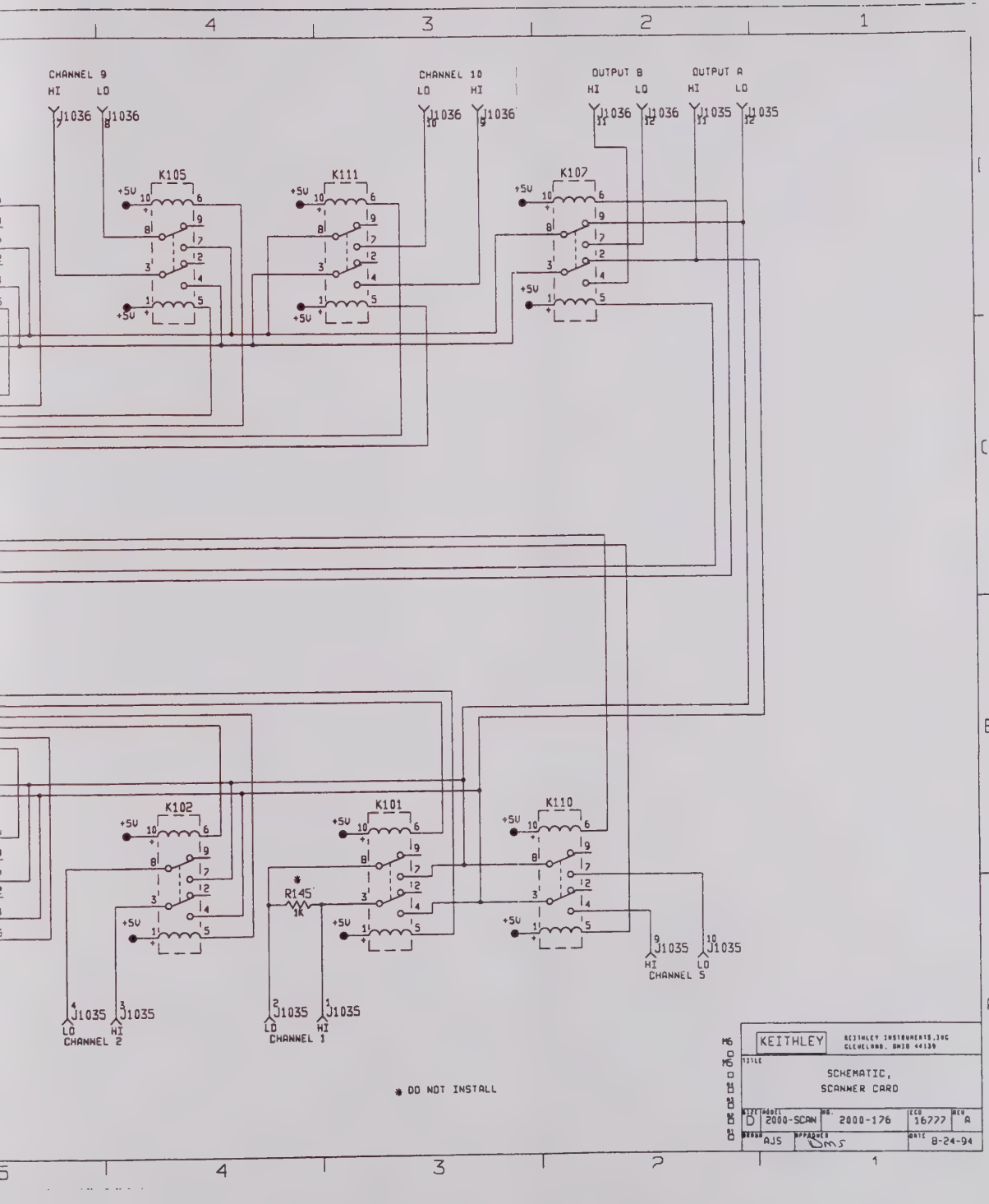
R146.

NOTE:
FOR COMPONENT INFORMATION, REFER TO 2000-SCAN PRODUCT STRUCTURE.

2000-SCAN	B2000-171	1
MODEL	NEXT ASSEMBLY	QTY.
USED ON		

DRAWING	DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED	DATE 9/22/94	SCALE 1:1	TITLE	COMPONENT LAYOUT, SCANNER BOARD
TRUMENTS INC. HIO 44139	XX=±.010 ANG.=±1°	DRN. AJS	ENG. APPR.		
	XXX=±.005 FRAC.=±1/64	MATERIAL ———	B	NO.	2000-170
	SURFACE MAX. 63	FINISH ———			


CHANNEL 6
HI LO
CHANNEL 7
HI LO
CHANNEL 8
HI LO
I.O.
STROBE
DATA
CLOCK
RESET
+5V
R146
R147
R134
C101
C102
C103
C104
C105
C106
C107
U1101
U1102
U1103
U1104
K106
K108
K104
J1036
J1035
NC
CHANNEL 4
CHANNEL 3


CHANNEL 9
HI LO
J1036 J1036
CHANNEL 10
LO HI
J1036 J1036
OUTPUT B
HI LO
J1036 J1036
OUTPUT A
HI LO
J1035 J1035
K105
K111
K107
K102
K101
K110
+5V
R145
1K
J1035 J1035
CHANNEL 2
J1035 J1035
CHANNEL 1
J1035 J1035
CHANNEL 5
* DO NOT INSTALL
KEITHLEY
KEITHLEY INSTRUMENTS,INC
CLEVELAND, OHIO 44139
SCHEMATIC,
SCANNER CARD
SIZE D
TABLE 2000-SCAN
NO. 2000-176
ECO 16777
REV A
DRAWN AJS
APPROVED
DATE 8-24-94

A
Specifications

GENERAL

10 Channels: 10 channels of 2-pole relay input.
All channels configurable to 4-pole.

Relay Type : Latching electro mechanical.

Actuation Time: <3.5ms.

CAPABILITIES: Multiplex one of ten 2-pole or one of five 4-pole signals into DMM.

INPUTS

Maximum Signal Level:

DC Signals: 110V DC, 1A switched, 30VA maximum (resistive load).

AC Signals: 125V AC rms or 175V AC peak, 100kHz maximum, 1A switched, 62.5VA maximum (resistive load).

Contact Life: $>10^5$ operations at maximum signal level; $>10^8$ operations cold switching.

Contact Resistance: <1Ω at end of contact life.

Contact Potential: <±500nV typical per contact, 1μV max.
<±500nV typical per contact pair, 1μV max.

Connector Type: Screw terminal, #22 AWG wire size.

Isolation Between Any Two Terminals: $>10^9\Omega$, <75pF.

Isolation Between Any Terminal and Earth: $>10^9\Omega$, <150pF.

Common Mode Voltage: 350V peak between any terminal and earth.

Maximum Voltage Between Any Two Terminals: 200V peak.

Maximum Voltage Between Any Terminal and Mainframe Input LO: 200V peak.

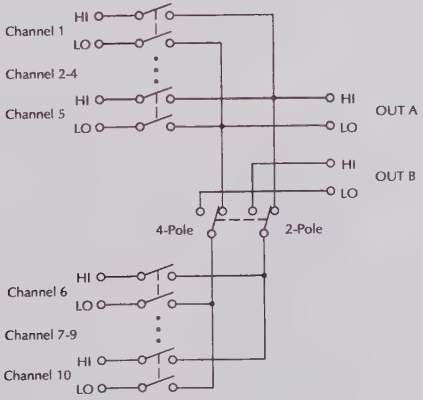
ENVIRONMENTAL:

Operating Environment: Specified for 0°C to 50°C.
Specified to 80% R.H. at 35°C.

Storage Environment: –40°C to 70°C.

DIMENSIONS, WEIGHT: 21mm high × 72mm wide × 221mm deep (0.83 in. × 2.83 in. × 8.7 in.). Adds 0.4kg (10 oz.).

SCANNER CONFIGURATION:



Specifications subject to change without notice.

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Service Form

Model No. _____ **Serial No.** _____ **Date** _____

Name and Telephone No. _____

Company _____

List all control settings, describe problem and check boxes that apply to problem. _____

_____

_____

❑ Intermittent ❑ Analog output follows display ❑ Particular range or function bad; specify

_____

❑ IEEE failure ❑ Obvious problem on power-up ❑ Batteries and fuses are OK

❑ Front panel operational ❑ All ranges or functions are bad ❑ Checked all cables

Display or output (check one)

❑ Drifts ❑ Unable to zero ❑ Unstable

❑ Overload ❑ Will not read applied input

❑ Calibration only ❑ Certificate of calibration required ❑ Data required

(attach any additional sheets as necessary)

Show a block diagram of your measurement including all instruments connected (whether power is turned on or not). Also, describe signal source.

Where is the measurement being performed? (factory, controlled laboratory, out-of-doors, etc.)_____

_____

What power line voltage is used?_____ Ambient temperature? _____ °F

Relative humidity? _____ Other? _____

Any additional information. (If special modifications have been made by the user, please describe.)

_____

_____

Be sure to include your name and phone number on this service form.

KEITHLEY

Keithley Instruments, Inc.
28775 Aurora Road
Cleveland, Ohio 44139

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